# Application of UAV and AI Technology for Real-time Detection of River Garbage

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## Abstract

[Objective] To explore the application of UAV and artificial intelligence technology in real-time river garbage detection in a coastal city, addressing the limitations of traditional monitoring methods.

[Method] The integration of UAV airports with AI edge computing is proposed to achieve efficient, real-time garbage detection and early warning. Two methods were compared: a color-based recognition method and a histogram image classification model.

[Results] The study demonstrates that the histogram image classification method exhibits superior performance in complex river environments, with higher accuracy and lower false positive rates.

[Limitations] The feasibility for rivers in other cities requires further investigation.

[Conclusion] This system possesses significant practical value for river garbage monitoring in this city.

## Full Text

## Preamble

**Application of Drone and Artificial Intelligence Technology in Real-Time River Garbage Detection**

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**Abstract:**
[Objective] This study explores the application of drone and artificial intelligence

(AI) technology for real-time river garbage detection in a coastal city, addressing the limitations of traditional monitoring methods. [Methods] The system integrates drone airports with AI edge computing to achieve efficient, real-time garbage detection and alerting. Two approaches were compared: a color-based recognition method and a histogram-based image classification model. [Results] The histogram-based image classification method demonstrated superior performance in complex river environments, achieving higher accuracy and lower false positive rates. [Limitations] Further research is needed to validate the system's feasibility in rivers of other cities. [Conclusions] The system exhibits significant practical value for river garbage monitoring in this urban context.

**Keywords:** Drone, Artificial Intelligence, Edge Computing, River Garbage, Real-Time Monitoring
**Classification Number:** TP393

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## 1.1 Background of the River Garbage Problem

In recent years, river garbage has become an increasingly severe environmental challenge, particularly in rapidly urbanizing coastal cities. River garbage not only degrades local water quality and ecosystems but also migrates through waterways to eventually become marine pollution. This situation threatens both the living environment of coastal residents and the health of marine ecosystems.

## 1.2 Limitations of Traditional River Garbage Monitoring Methods

Traditional river garbage monitoring methods such as fixed cameras, manual patrols, and surface cleaning vessels have played a role but suffer from limited coverage and delayed data acquisition. Fixed cameras can only monitor localized river sections and cannot respond to dynamic changes in real time. Manual patrols are time-consuming, labor-intensive, and costly, making them impractical for sustained, large-scale waterway monitoring. Additionally, the fluidity of river garbage, its irregular distribution patterns, and influence from multiple factors including climate and terrain render monitoring tasks particularly challenging.

## 1.3 Advantages of Integrating Drones and AI

Advances in technology have provided new solutions through drone technology and artificial intelligence. Drones offer flexibility, efficiency, and broad coverage, enabling rapid capture of real-time images across extensive river areas and dramatically improving monitoring efficiency. Simultaneously, developments in AI—particularly deep learning—have endowed machines with the capability to automatically analyze images and detect garbage. Integrating drones with AI enhances both the coverage and real-time performance of monitoring operations.

## 1.4 Technical Challenges in River Garbage Detection

River garbage detection presents particularly challenging tasks in waterbody monitoring. Garbage types in rivers are diverse, including plastic bags, bottles, branches, paper scraps, and more. These items vary in size, color, and shape, exhibiting different visual characteristics under varying light and water flow conditions. Furthermore, changes in water quality and surface conditions—such as turbidity, sunlight reflection, and wave motion—interfere with image clarity, creating additional complexity for AI recognition models.

The rivers in this coastal city exhibit distinct color characteristics with calm, uniformly colored surfaces, making color-based garbage detection methods effective under specific conditions. For example, brightly colored garbage (such as plastic bags) floating on clear water is relatively easy to detect. However, when water color is complex or garbage colors resemble the water surface, the detection accuracy of color-based methods declines significantly. To address this, we propose an alternative deep learning model based on histograms and image classification that achieves higher detection precision through extraction and analysis of image features.

## 1.5 Research Motivation

Building upon this background, this paper proposes a real-time river garbage detection system that integrates drone technology with AI edge computing. The system aims to capture images of river surface garbage using drones, perform image analysis with AI technology to automatically identify garbage and its location, and promptly send alerts to relevant authorities for timely cleanup. This approach offers the advantage of rapidly and accurately obtaining monitoring results without relying on fixed camera equipment or cloud-based data analysis. This study also compares the performance of color-based recognition methods against histogram-based deep learning image classification models. Experimental results demonstrate that the latter offers superior accuracy and robustness when handling complex waterway garbage detection tasks.

## 2.1 Drone Detection Module

The drone detection module serves as the front-end component of the system, responsible for capturing high-resolution images of river surface garbage. The drone conducts automatic cruises along preset flight paths while making real-time adjustments based on actual conditions. For instance, upon discovering garbage-concentrated areas, the drone can reduce altitude or hover to obtain more detailed image data.

Equipped with high-resolution cameras and GPS positioning systems, the drone ensures precise image acquisition and complete coverage. This system employs the DJI Drone Airport 2 and its associated drones.

## 2.2 AI Edge Computing Module

The AI edge computing module forms the core of the system, processing image data collected by the drone and performing garbage detection. Deployed on edge computing devices near the data source, this module utilizes an NVIDIA Jetson high-performance processor with 100 TOPS computing power. This approach enables real-time processing of large volumes of image data while avoiding latency issues associated with cloud-based processing.

## 2.3 Color-Based Recognition Method

The color-based garbage detection method relies primarily on the uniformity of water surface color. The system detects objects that significantly differ from water color (i.e., garbage) by analyzing color distribution in water regions of the image. When a portion of the image deviates noticeably from the normal water color range, the system marks that region as potential garbage. This method works well in environments with relatively uniform water color and conspicuous garbage colors but proves limited when water color is complex or garbage colors resemble the water surface.

## 2.4 Histogram-Based Image Classification Method

In contrast to color-based methods, the histogram-based image classification approach leverages more sophisticated image features. This method generates color histograms of images and combines them with deep learning models (such as Convolutional Neural Networks, CNN) for image classification. The CNN model, trained to recognize different garbage types and distinguish them from the background, demonstrates greater robustness against complex backgrounds and lighting variations compared to color-based methods.

## 2.5 Data Transmission and Processing

Image data captured by the drone is transmitted to edge computing devices via a low-latency wireless communication system to ensure real-time processing. The entire system employs 5G wireless communication technology to maintain stable and rapid transmission of large-volume image data.

## 2.6 Alert Module

When the AI model detects garbage in images, the system generates alerts and notifies relevant authorities via WeChat. The alerts include garbage location, type, and detection confidence information to help authorities take prompt action and enable leadership to monitor river pollution conditions.

### 3.1 Dataset Collection and Preparation

To validate the system's adaptability across different environments, we selected a typical river in a coastal city for data collection. This river features a uniformly colored surface. The drone conducted multiple flight missions under various weather conditions—including sunny, cloudy, and rainy days—to ensure sufficient diversity in the collected image data and effective coverage of complex river environments.

During each flight, the drone scanned the river along preset paths while capturing high-resolution images in real time, as shown in Figure 1 [Figure 1: see original paper]. These images were subsequently transmitted to edge computing devices for preprocessing to eliminate noise and segment garbage-related regions, as shown in Figure 2 [Figure 2: see original paper].

### 3.2 Model Training and Validation

This study employed a Convolutional Neural Network (CNN) for training on histograms (see Figure 4 [Figure 4: see original paper]). The model training process included hyperparameter tuning such as learning rate, batch size, and network depth. After training, we tested the model using a validation set comprising images never seen by the model. Results indicated that the CNN model achieved over 90% detection accuracy on the validation set while maintaining false positive rates (i.e., misidentifying non-garbage regions as garbage) below 5%.

### 3.3 Performance Comparison: Color-Based vs. Histogram-Based Methods

To evaluate different image processing approaches, we conducted experimental comparisons between color-based detection methods and histogram-based deep learning image classification models. Results showed that the color-based method performed well in clear water with conspicuous garbage colors, rapidly detecting garbage that differed significantly from water color with an average detection time of 10 milliseconds. However, under complex water color conditions and variable lighting, this method exhibited high false positive rates and significantly reduced detection accuracy.

In contrast, the histogram-based image classification model demonstrated more stable performance across diverse environments, as shown in Figures 3 [Figure 3: see original paper] through 6 [Figure 6: see original paper]. This method not only effectively handled complex water bodies and lighting variations but also maintained high accuracy across multiple garbage types (such as plastic bags, food containers, etc.). Experiments revealed that the histogram-based model required approximately 120 milliseconds for detection—slightly longer response time but substantially superior accuracy compared to the color-based method. Particularly under poor lighting or when garbage colors resembled the water surface, the histogram-based model achieved higher detection precision by learning more complex features such as texture and shape, as shown in Table 1 .

**Table 1: Performance Comparison of Color-Based and Histogram-Based Methods**

| Evaluation Dimension | Color-Based Detection Method | Histogram-Based Image Classification Model |
|---|---|---|
| Applicable Conditions | Suitable for clear water with conspicuous garbage colors | Suitable for multiple garbage types, adaptable to complex water and lighting conditions |
| Response Time | 10 milliseconds | 120 milliseconds |
| Environmental Adaptability | Poor adaptability to complex water and lighting conditions | Strong adaptability, particularly effective under poor lighting and when garbage colors approach water color |

## 3.4 Discussion of Experimental Results

Experimental results demonstrate that while color-based methods perform adequately in specific scenarios, their limitations become apparent—particularly under complex environmental conditions. In contrast, the histogram-based deep learning image classification model exhibits more stable performance across various scenarios. Its higher detection accuracy and lower false positive rate make it more suitable for complex river garbage detection tasks. Although its response time is slightly longer, this difference has minimal impact on overall system performance in practical applications. For large-scale river monitoring tasks, the higher accuracy significantly reduces the need for manual re-inspection, thereby improving overall efficiency.

This study proposes a river garbage detection system combining drone technology with AI edge computing and validates its effectiveness in complex environments. By comparing color-based detection methods against histogram-based deep learning models, results show that the latter offers significant advantages in detection accuracy and robustness, particularly under poor lighting or complex water quality conditions. The integration of drone technology and AI edge computing provides new perspectives for future environmental monitoring, enhancing detection efficiency while enabling real-time alerts to help relevant authorities respond swiftly.

## 4.1 Extended Application Domains

Future work will focus on expanding the system's application domains and further optimizing performance for broader waterbody monitoring tasks, such as lake and ocean garbage detection. By extending algorithms and techniques, this system can adapt to more complex water environments—including rivers with non-uniform colors—to advance technology applications in water environmental protection.

## 4.2 System Scalability

Future research will explore system scalability, investigating how distributed system design can enable multiple drones to work collaboratively for monitoring larger-scale rivers or cross-regional waterbodies. Cooperative operation of multi-drone systems will substantially enhance monitoring coverage and efficiency.

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## Author Contributions Statement

Guo Feng: Conceived research ideas, designed research methodology; conducted experiments; drafted manuscript; revised final version.

*Note: Figure translations are in progress. See original paper for figures.*